Next Generation Internet (NGI) Implementation to Serve Visible Human Datasets Phase II: Development of Test Beds
N01-LM-8-5630

Presented by
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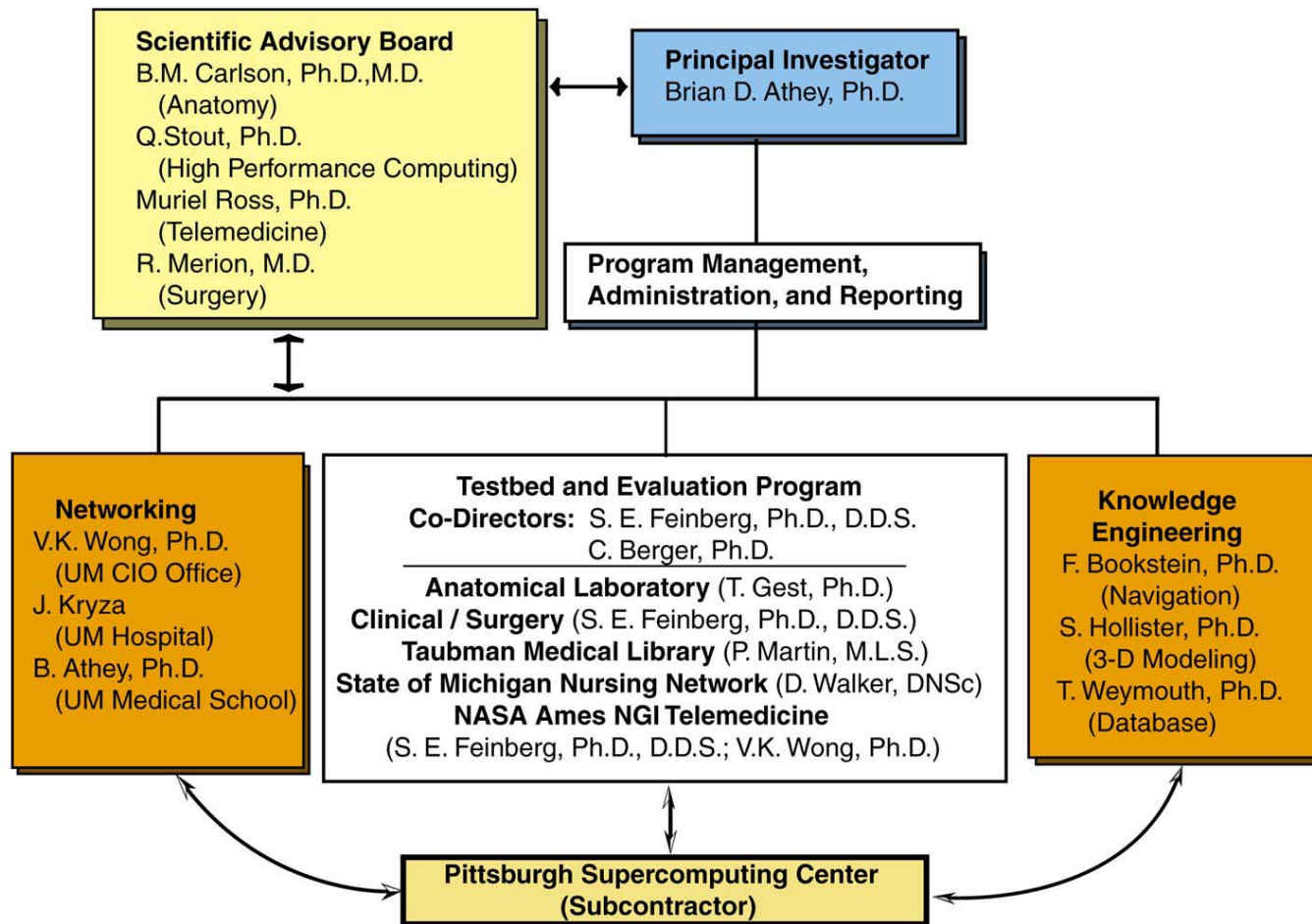
UM Office Vice President for Research (OVPR)

The University of Michigan

Ann Arbor, Michigan

http://vhp.med.umich.edu *http://CTAalliance.org*

August 28, 2003

The Original Team from 1998 is Largely Intact Today!

Scientific Advisory Board
B.M. Carlson, Ph.D.,M.D.
  (Anatomy)
Q.Stout, Ph.D.
  (High Performance Computing)
Muriel Ross, Ph.D.
  (Telemedicine)
R. Merion, M.D.
  (Surgery)

Principal Investigator
Brian D. Athey, Ph.D.

Program Management, Administration, and Reporting

Networking
V.K. Wong, Ph.D.
  (UM CIO Office)
J. Kryza
  (UM Hospital)
B. Athey, Ph.D.
  (UM Medical School)

Testbed and Evaluation Program
Co-Directors: S. E. Feinberg, Ph.D., D.D.S.
C. Berger, Ph.D.
Anatomical Laboratory (T. Gest, Ph.D.)
Clinical / Surgery (S. E. Feinberg, Ph.D., D.D.S.)
Taubman Medical Library (P. Martin, M.L.S.)
State of Michigan Nursing Network (D. Walker, DNSc)
NASA Ames NGI Telemedicine
(S. E. Feinberg, Ph.D., D.D.S.; V.K. Wong, Ph.D.)

Knowledge Engineering
F. Bookstein, Ph.D.
  (Navigation)
S. Hollister, Ph.D.
  (3-D Modeling)
T. Weymouth, Ph.D.
  (Database)

Pittsburgh Supercomputing Center
(Subcontractor)

Major Project Deliverables

- Demonstration and Use of VH Data for 40 Simultaneous Users in UM Gross Labs Using NGI from PSC. Infrastructure scales to 1000's of simultaneous users.

- 3 Working Navigators and Several Browsers Now available for download and/or remote use. Products interact with Surface and Labels databases.
    - UM Edgewarp 3.4.x (LINUX/MAC, PC Coming)
    - UM iVoxel Browser 2.0 (Mono and Stereo, PC and Mac)
    - PSC Volume Browser (Platform Independent)
    - UM Regional Browsers with Registered MRI and CT Data)

    Working NGI Server Infrastructure at UMich and PSC with VH Content, DB, Compute Servers and Content Creation Tools

    ~400 Segmented and Labelled VHF Structures Labelled with Controlled Vocabulary and Querable using Rosse FMA

    Gross Anatomy and Nursing Test-beds Established for Further Collaborative Development and Study

    5 Major National/International Demonstrations (2 NASA NREN, iGrid 2002, I2, University of Hong Kong Nursing School)

    At least 7 Peer Reviewed Publications and >50 Abstracts

    2 Ph.D. Dissertations (1 in CS and 1 in Education)
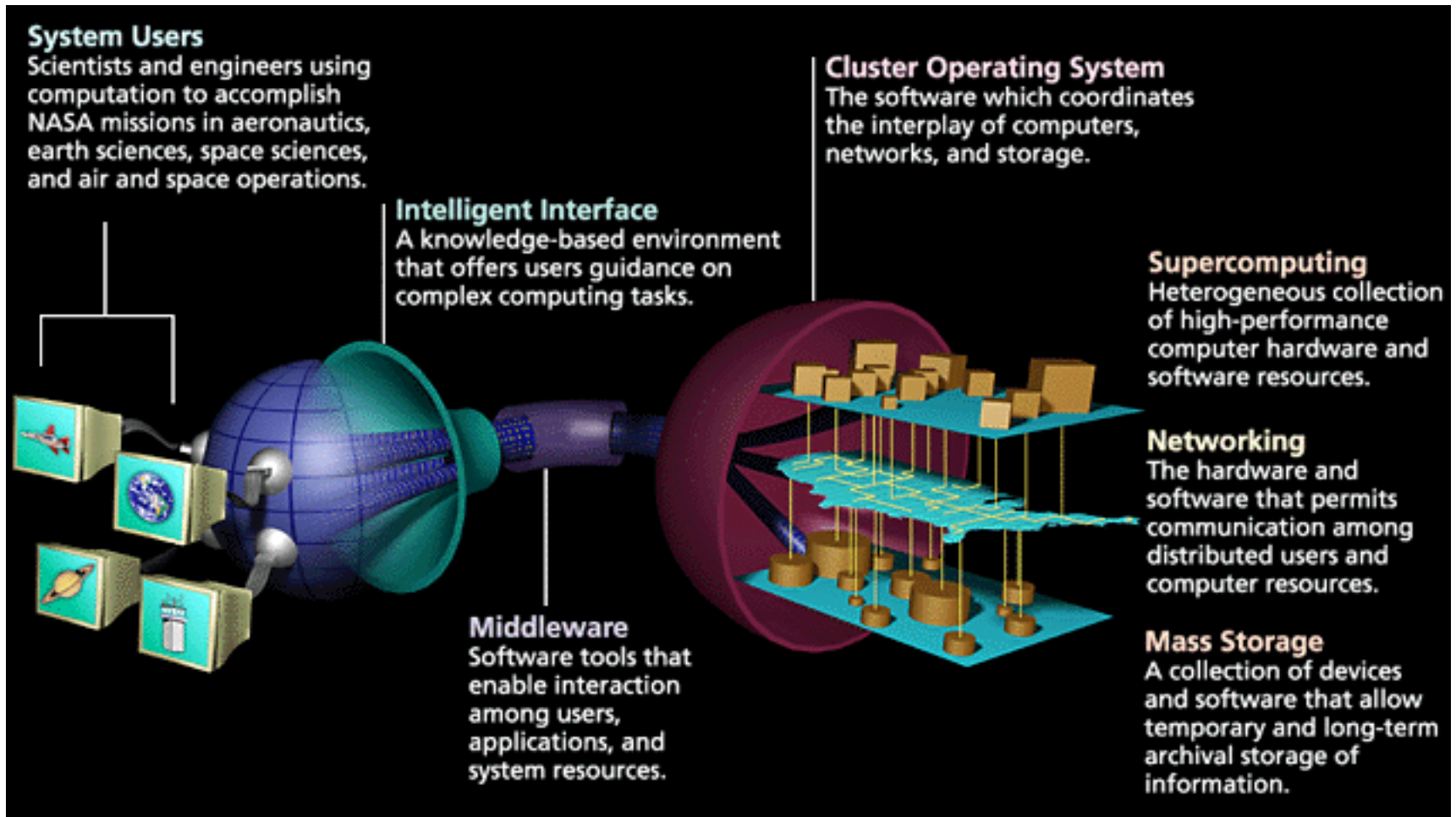
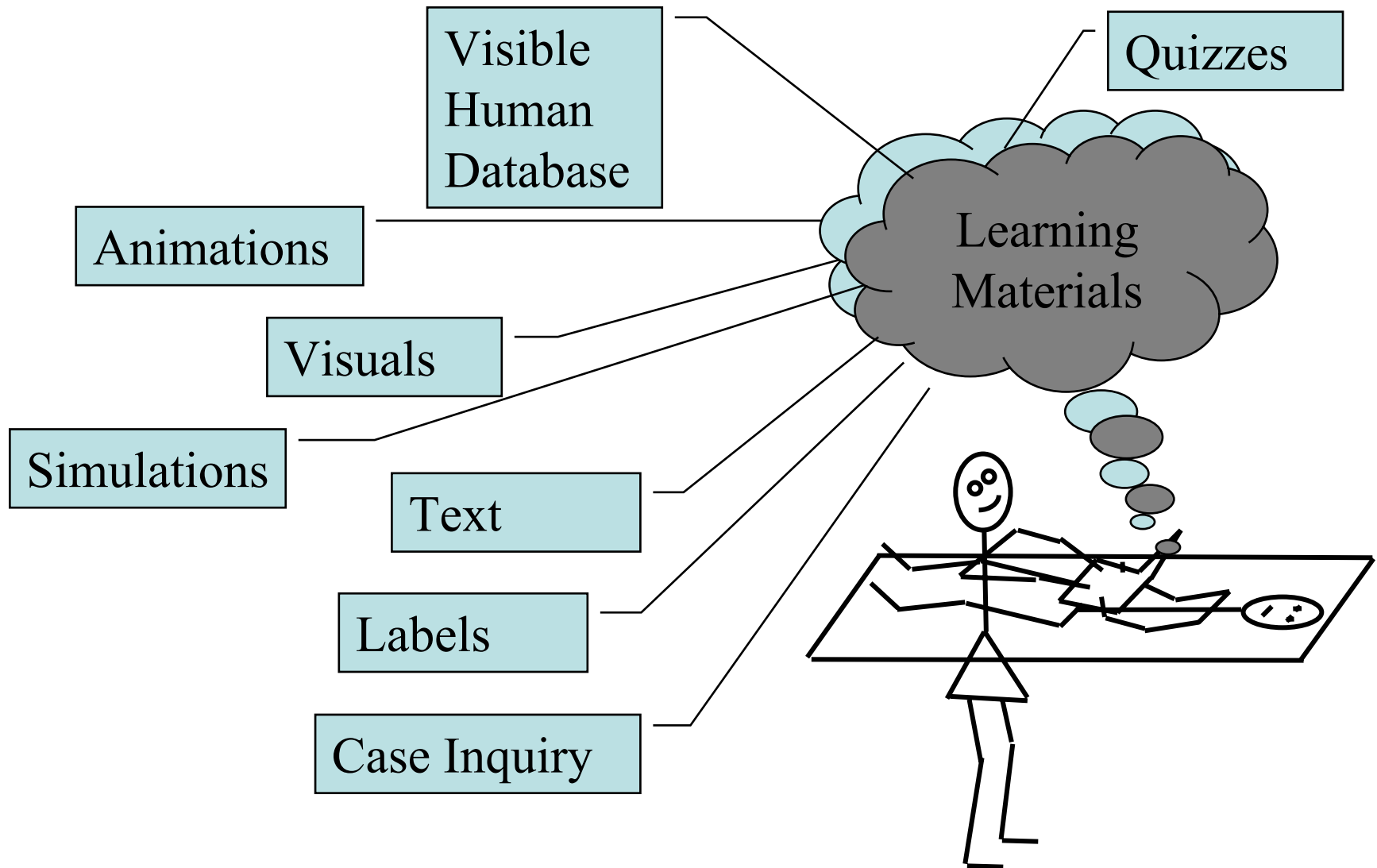# Development Focus: Visible Human Project
(courtesy Don Jenkins, NLM)

Natural Biologic Variation

**Clinical Patterns
Signs & Symptoms
Pathophysiology**

VISIBLE HUMAN DATASETS

*Disease and Pathology
Normal Variation*

Teaching Applications

Public Domain Web Sites

**Biological
Structure
Continuum**

**Structural Change
Scale & Resolution**

*Development
Aging*

**Embryology
Gross Anatomy
Micro Anatomy
Sub Microscopic
Physiology
Biochemistry**

ANCILLARY DATA SETS

National Anatomy Archive

DIGITAL HUMAN SIMULATION

**MRI, CT, PET
Radiology
Anatomic**

The Evolving Amphitheater of Human Anatomy
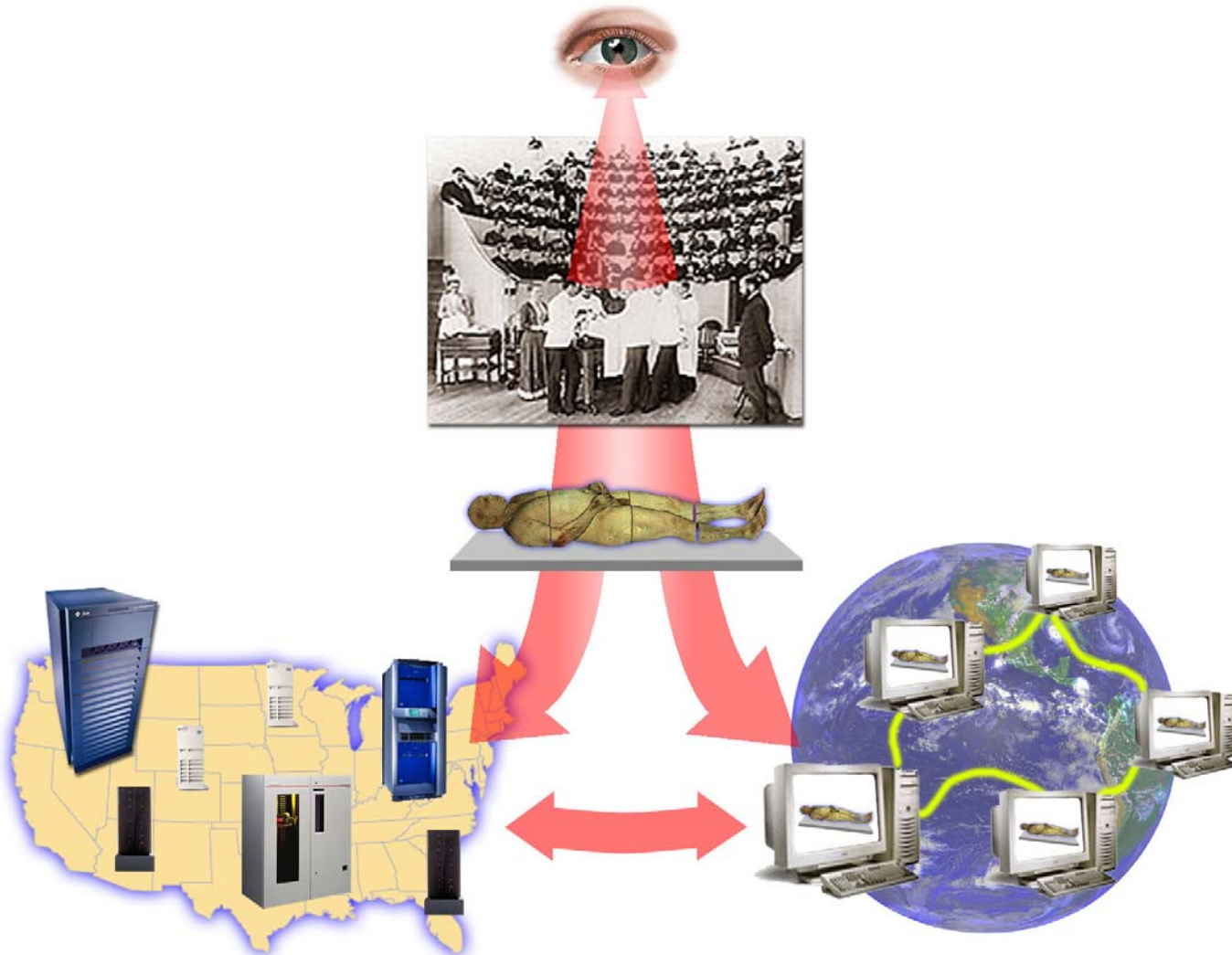
Visible Human Infrastructure Development Embraces "Cyberinfrastructure" Vision

System Users
Scientists and engineers using computation to accomplish NASA missions in aeronautics, earth sciences, space sciences, and air and space operations.

Intelligent Interface
A knowledge-based environment that offers users guidance on complex computing tasks.

Middleware
Software tools that enable interaction among users, applications, and system resources.

Cluster Operating System
The software which coordinates the interplay of computers, networks, and storage.

Supercomputing
Heterogeneous collection of high-performance computer hardware and software resources.

Networking
The hardware and software that permits communication among distributed users and computer resources.

Mass Storage
A collection of devices and software that allow temporary and long-term archival storage of information.

Strategy and Tactics: Integrate VH into Medical and Nursing Student User Products

Deliverable: The Visible Human Datasets are mapped into and used by all Gross Anatomy Trainees at UMich using the PSC Volume Browser
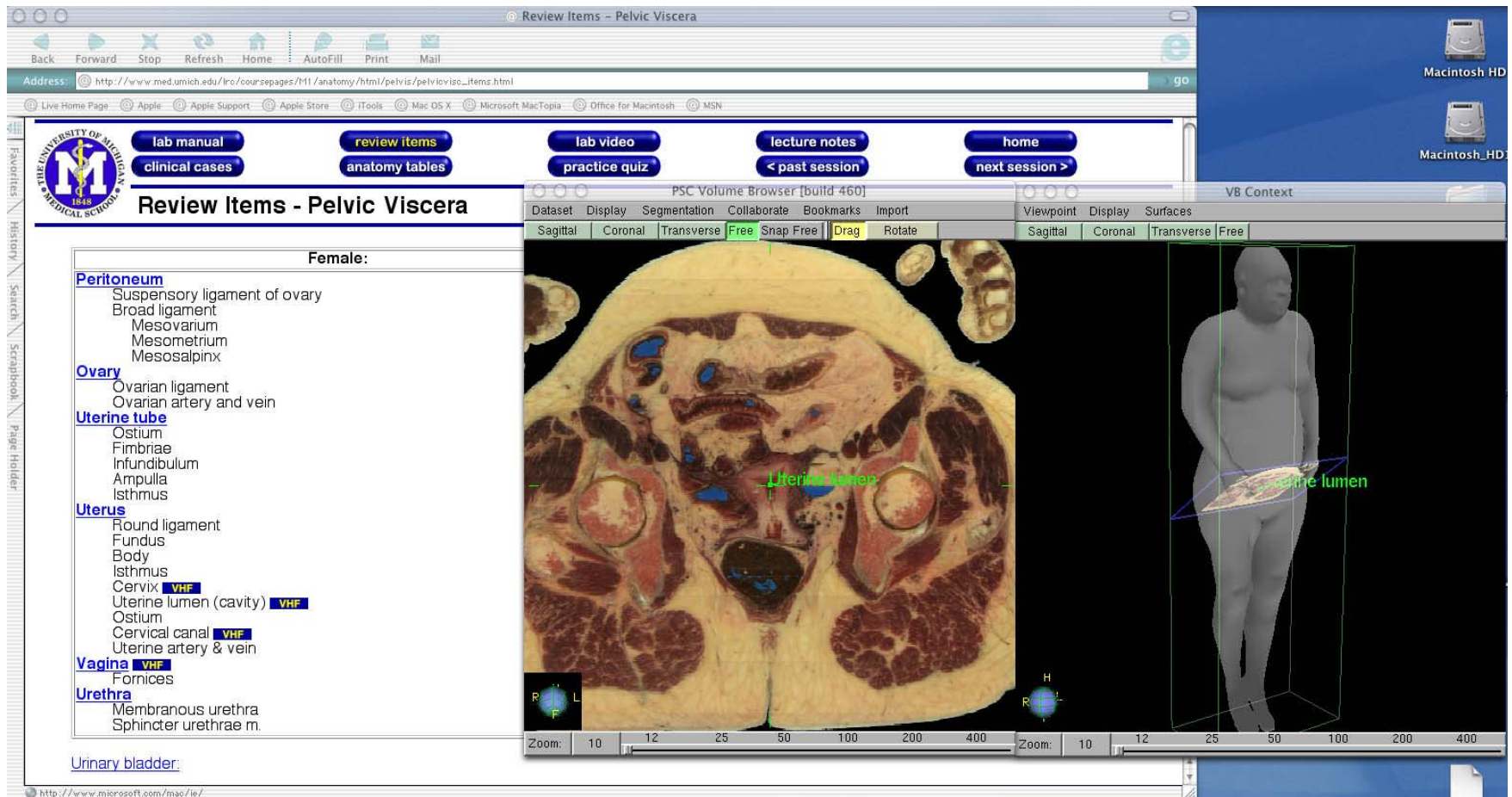
Interactive Surface and Volume Content is being utilized by students now

Integration of VH, and Volume/Structure/ Instructional Databases

Volume/Structure/Instructional Space

Area	Structure	Volume
	Labels	

UMLS   MESH   TA

User Request

XML Tagged

Arbitrary Section

Rotation-Translation Parameters

XML Tagged

Navigable Volume Data

User Skill Instruction Area				
Dental	Surgery	Nursing	Anatomy	Allied Health
Audio				
Video				
Quizzes				
Tests				

Walter Meixner
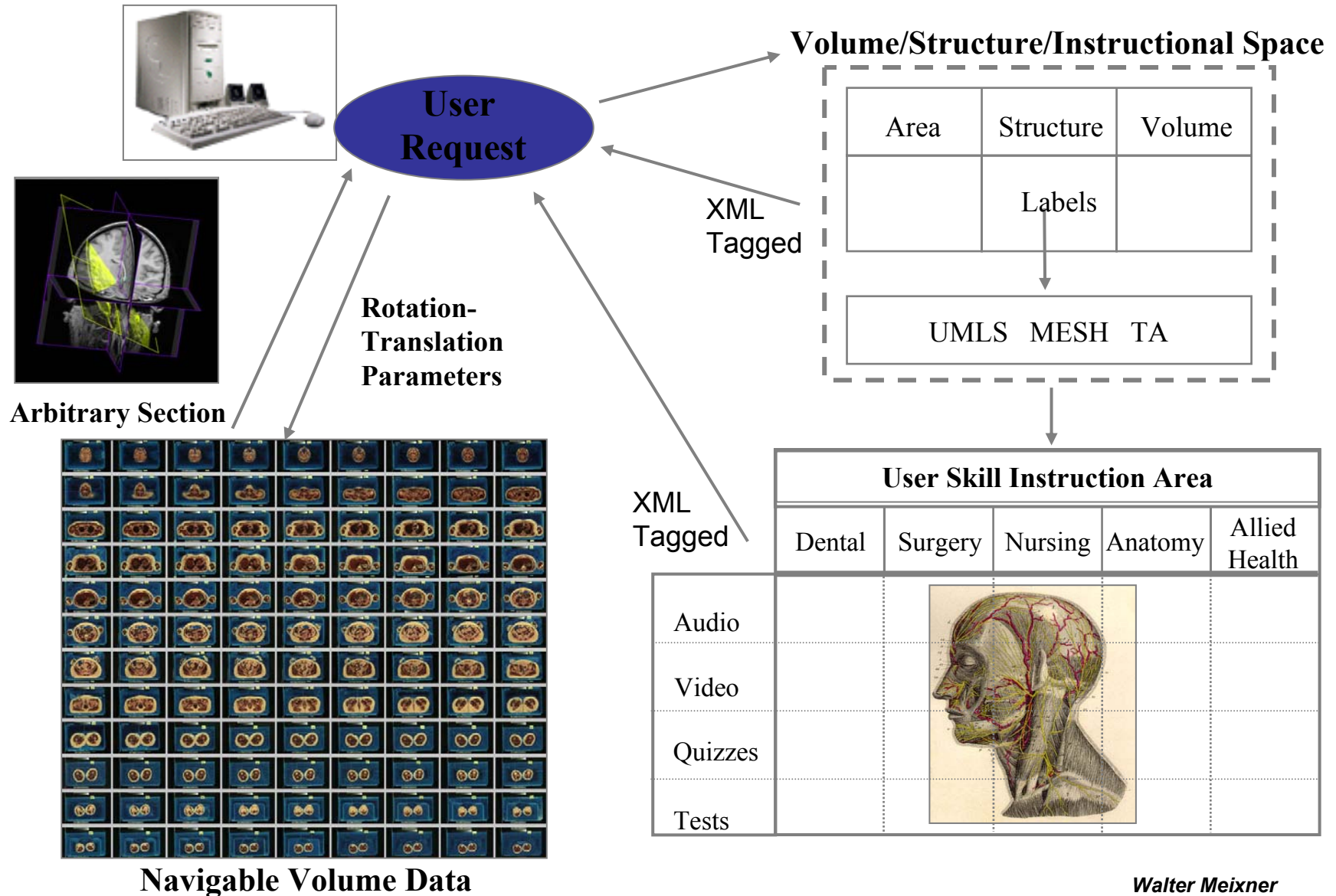
Final UM/PSC System Architecture

Volume Server

Router or Hub

(NGI)

Anatomy
Database

Mesh
Server

Voxel Identity
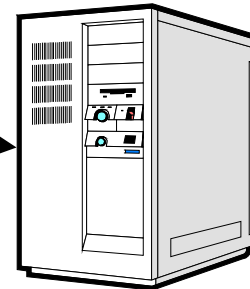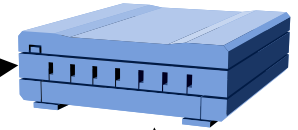Server

Collaborative
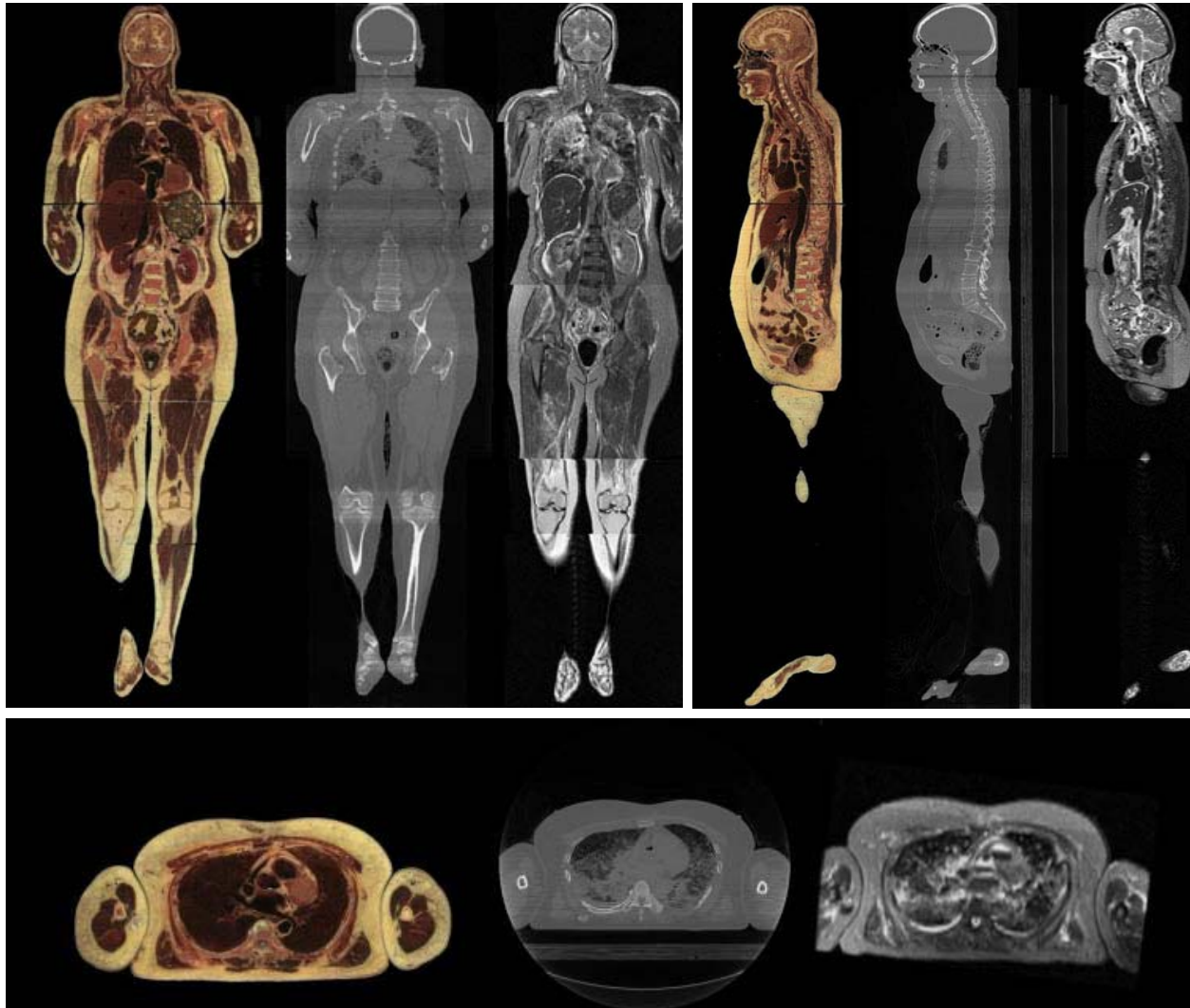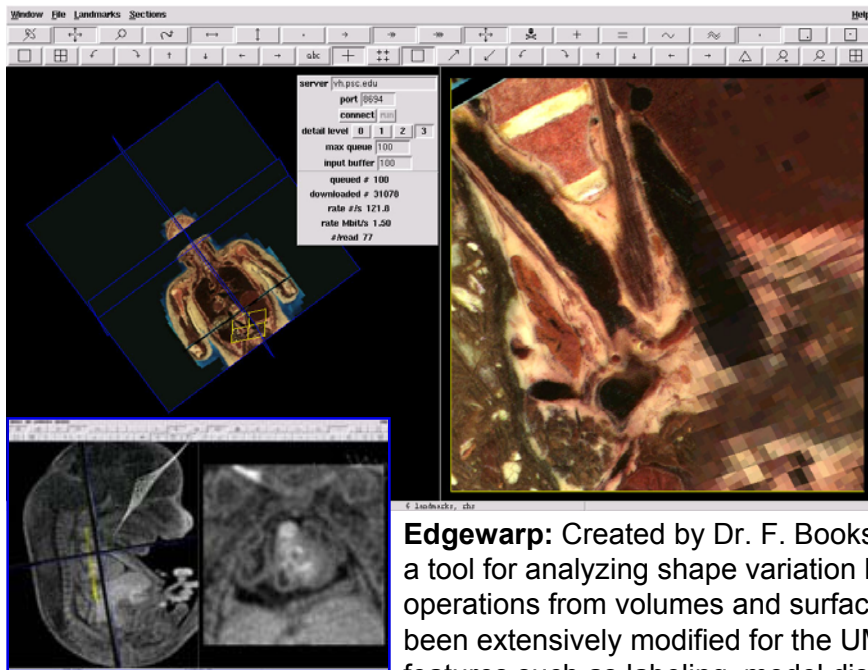Server

Intermediate
Server
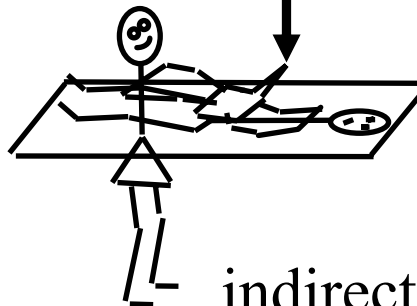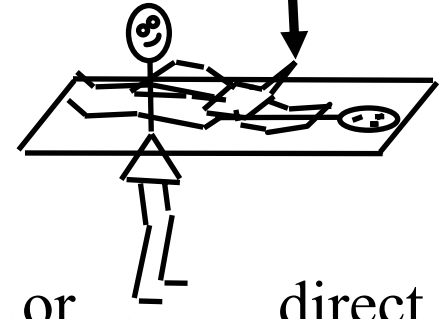
indirect   …or…   direct

A Promise to Dr. Lindberg in 1998: All the Data is on the www (http://vhp.med.umich.edu)

UMich Visible Human Project NGI/I2 Network-Enabled Software Tools and Content

Java Browser:
Alexander Ade has created a set of Java-based Browsers that allows web-based volume visualization as either slices or volume-rendered scenes.
The applications show anatomical labels queried from an database and displays 3-D models in either mono or stereo views.

Java Browser - Model View

Edgewarp: Created by Dr. F. Bookstein and Dr. W. Green as a tool for analyzing shape variation by extracting invariant geometric operations from volumes and surfaces, this software program has been extensively modified for the UM VH Project. The addition of features such as labeling, model display and filmstrip creation has expanded its usefulness to medical education.
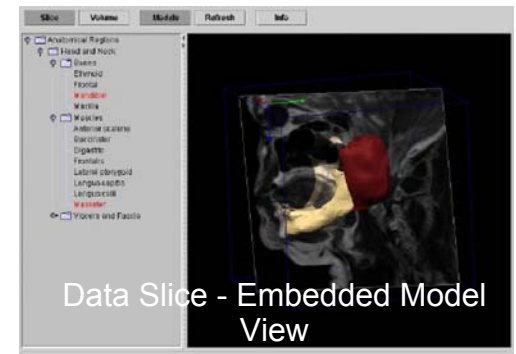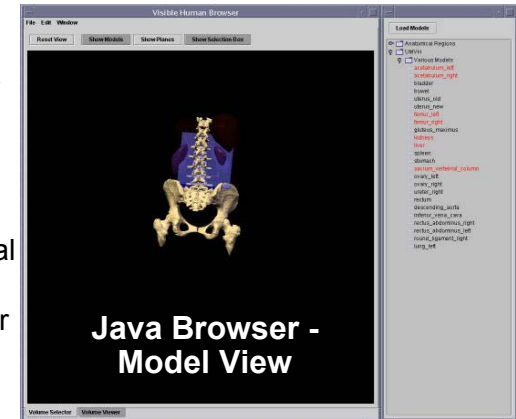

Stereo Volume
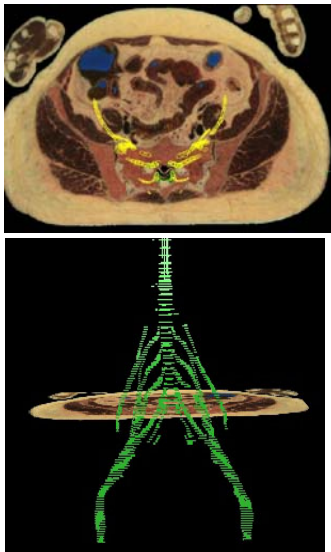
Pittsburgh Supercomputing Center (PSC)
Segmentation Tool: To facilitate the creation of surface models, our collaboration partner the PSC has been commissioned with the development of a segmentation tool for the production of contours. This tool has been ported to Linux, Mac and Windows platforms.
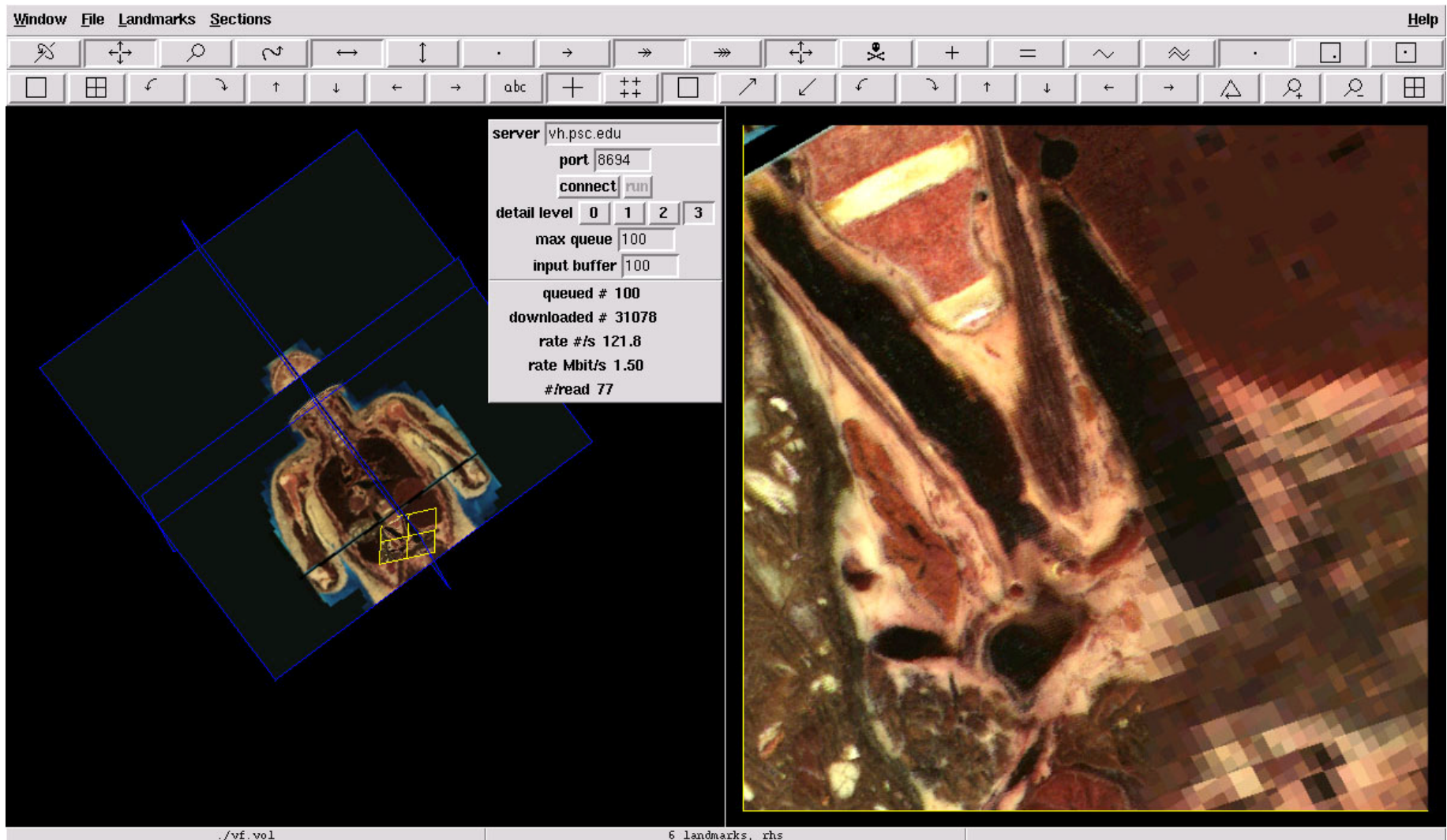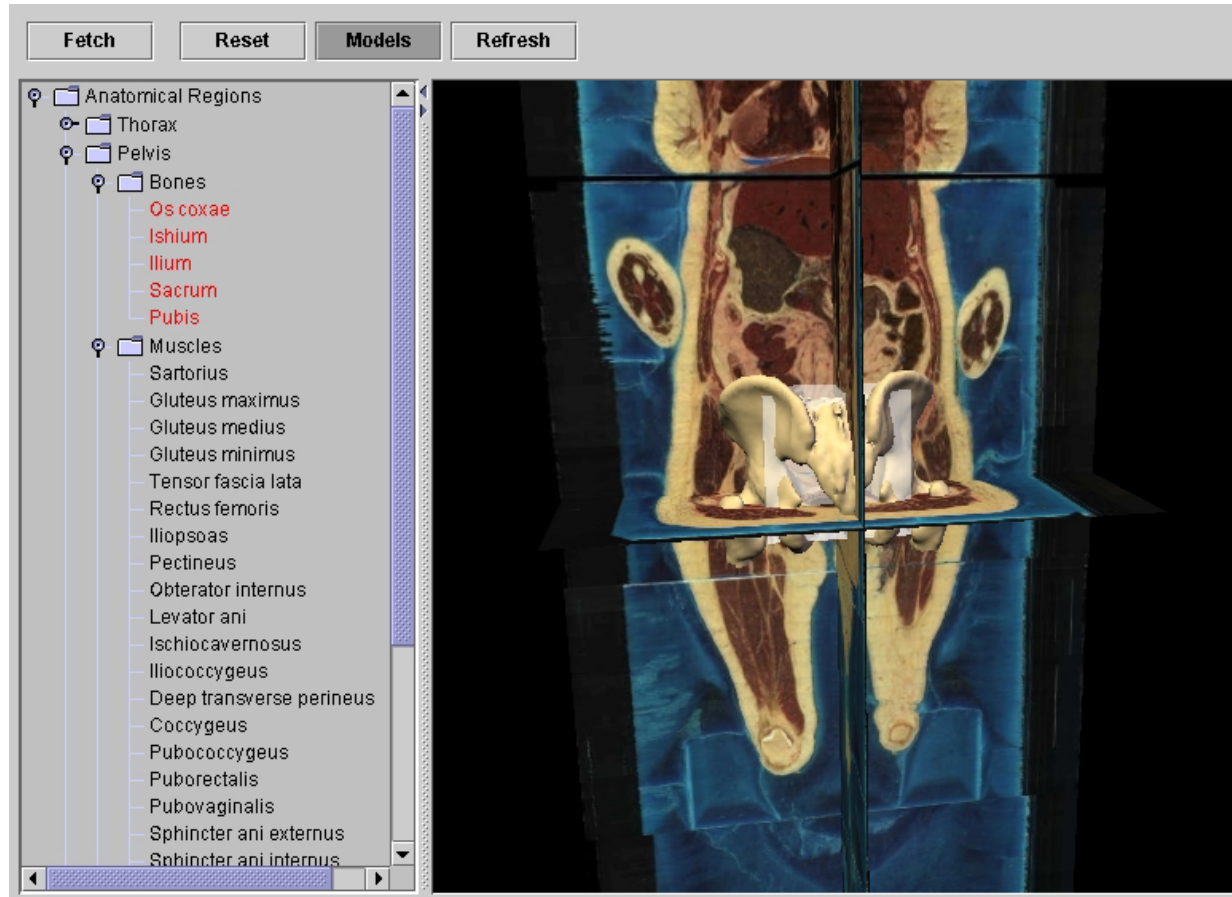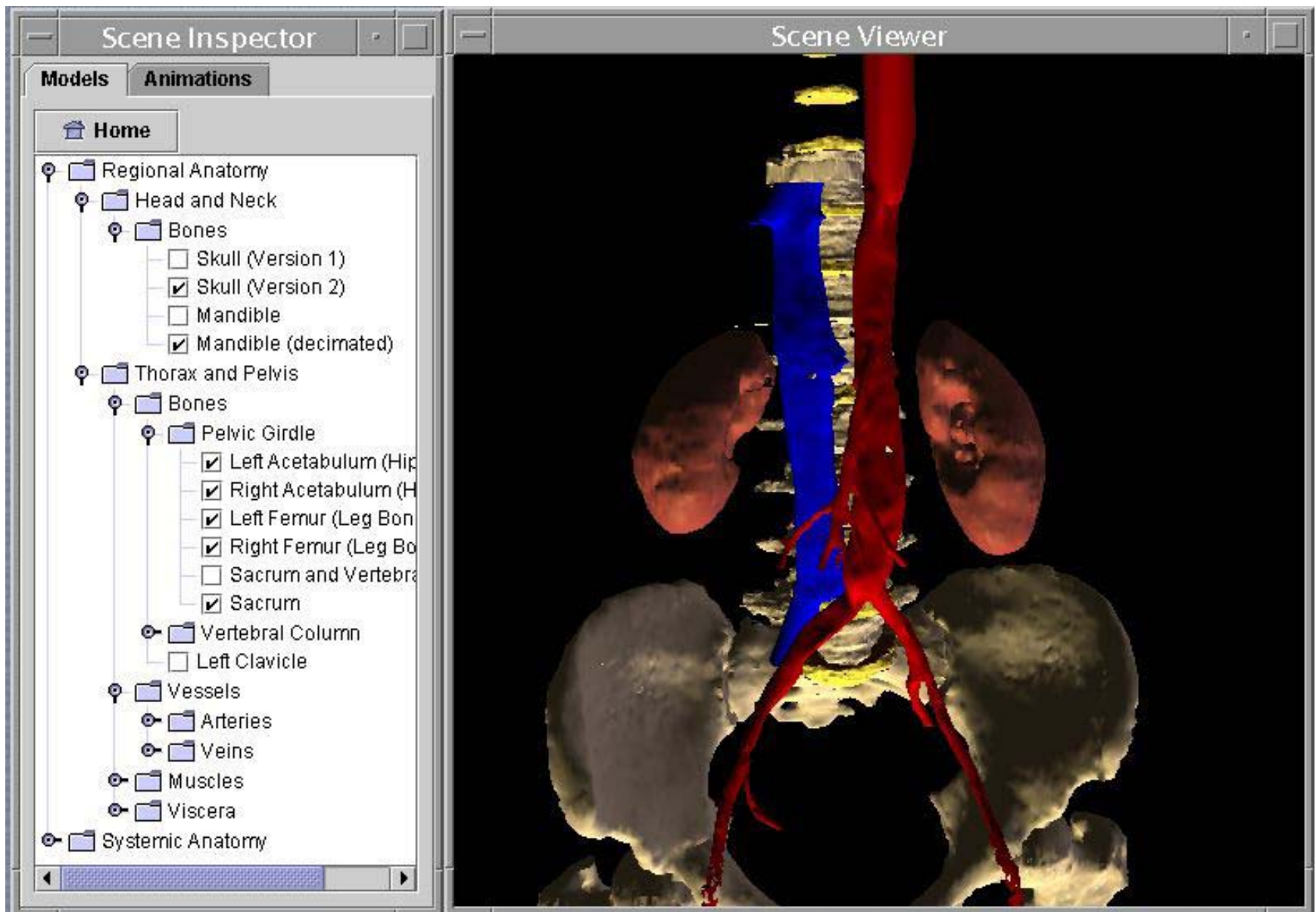

Data Slice - Embedded Model View

Edgewarp has been our Prototyping Platform for over 12 Years
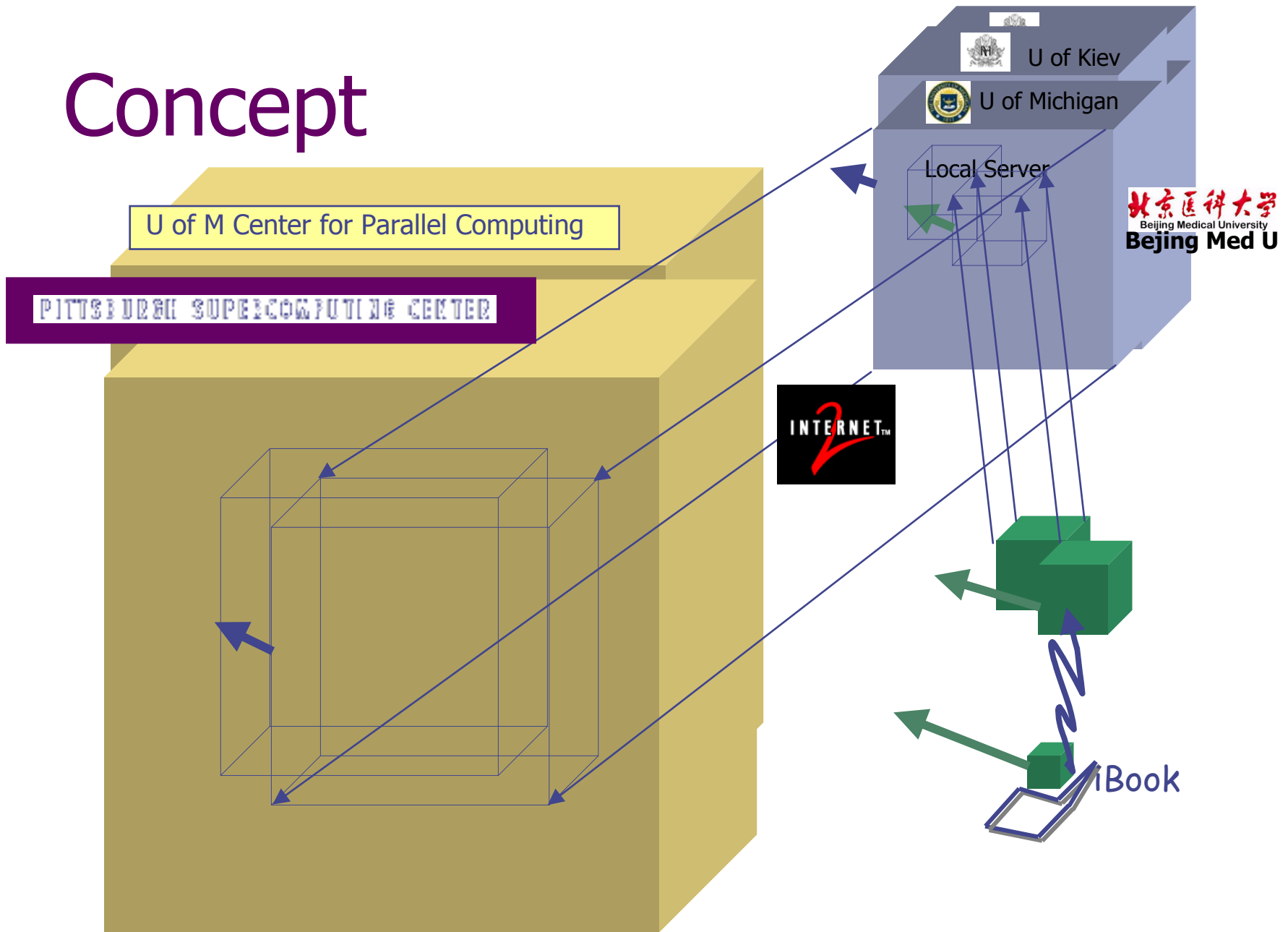## (to be Demonstrated)

Alex Ade's Demonstration to NLM December 2000 (iVoxel Browser 1.0)

iVoxel Browser 2.0 (to be Demonstrated)

Concept

U of M Center for Parallel Computing

PITTSBURGH SUPERCOMPUTING CENTER

U of Kiev

U of Michigan

Local Server

北京医科大学
Beijing Medical University
Bejing Med U

INTERNET 2

iBook

Context of Integration for the NGI VH within the UM Medical School IT/Computing Architecture For Life and Health Sciences Informatics
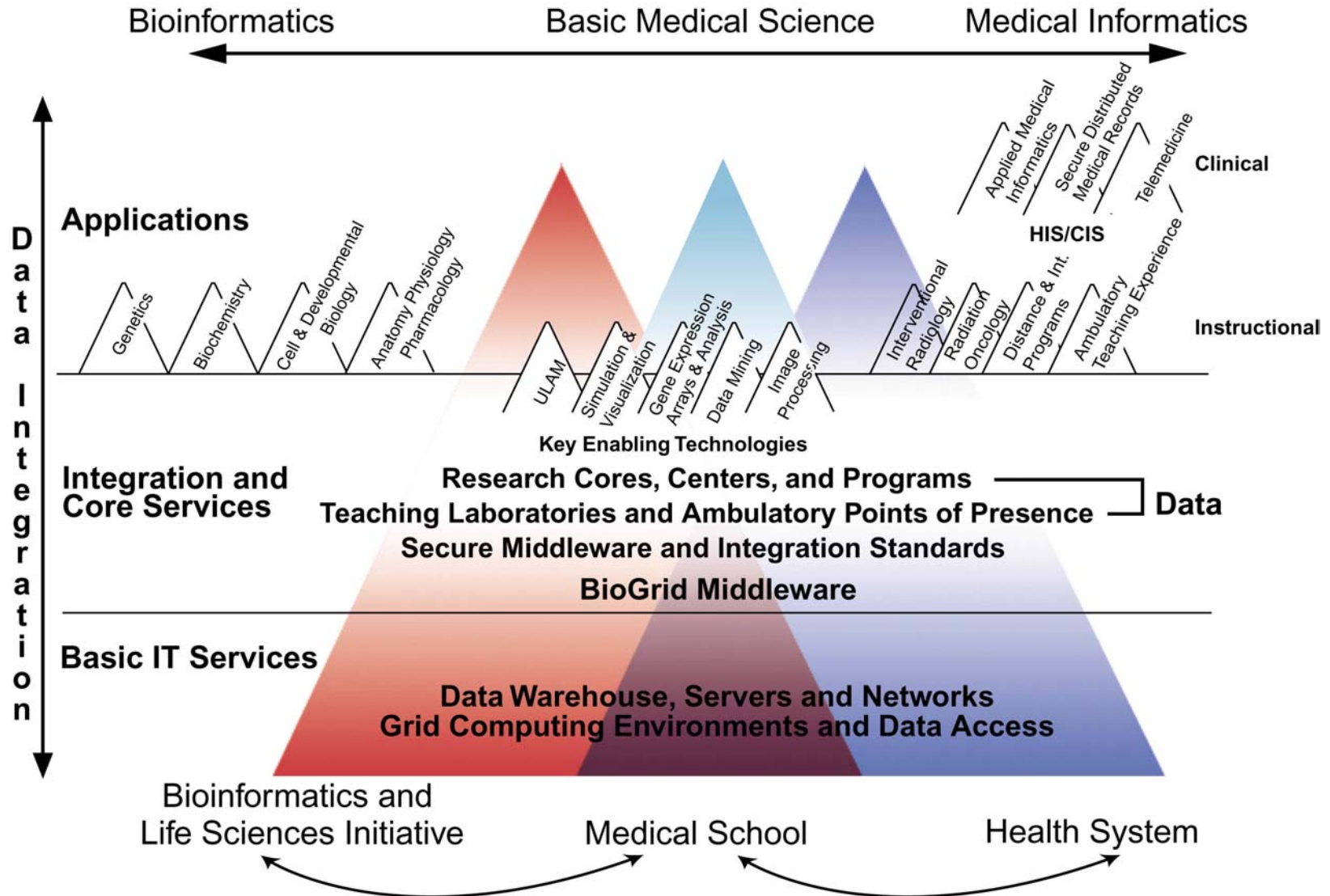
UMich Visible Human Knowledge Base Schematic

Annotation layer

- Hyperlinked texts
- Movies
- Sounds, etc

Semantic layer

- Medical lexicons
- Semantic relations
- Links to regions, volumes, and annotations

Anatomical layer

- Labels of structures
- Voxel data and segmentation
- Volume surfaces
- Spatial relationships
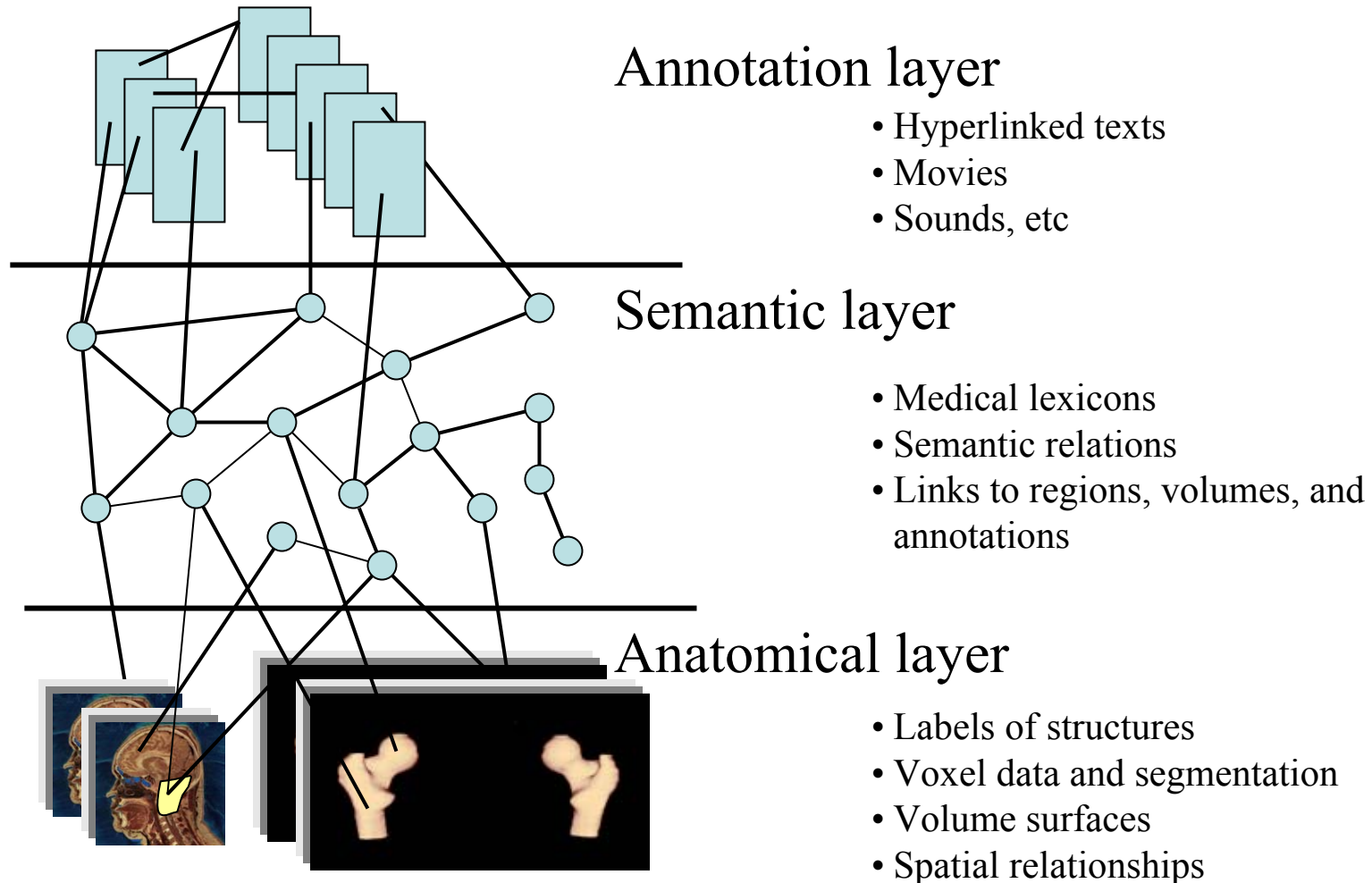
Original Labeling Scenario

System: Skeletal Muscle
Region: Pelvic
Structure: Sartorius

Boundaries
Contains
Surface Anatomy
Common Anomalies
Illustrations

Action
Origin
Insertion
Innervation
Arterial
Venous
Bounded by

Femoral Nerve

Source
Branches
Motor
Sensory

lumbar plexus
(ventral primary rami
of spinal nerves L2-L4)
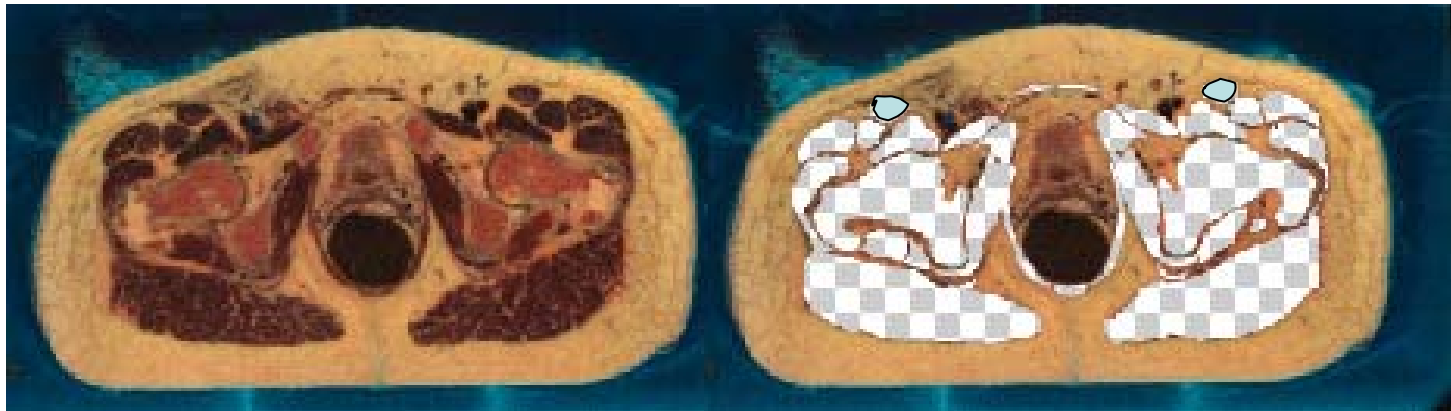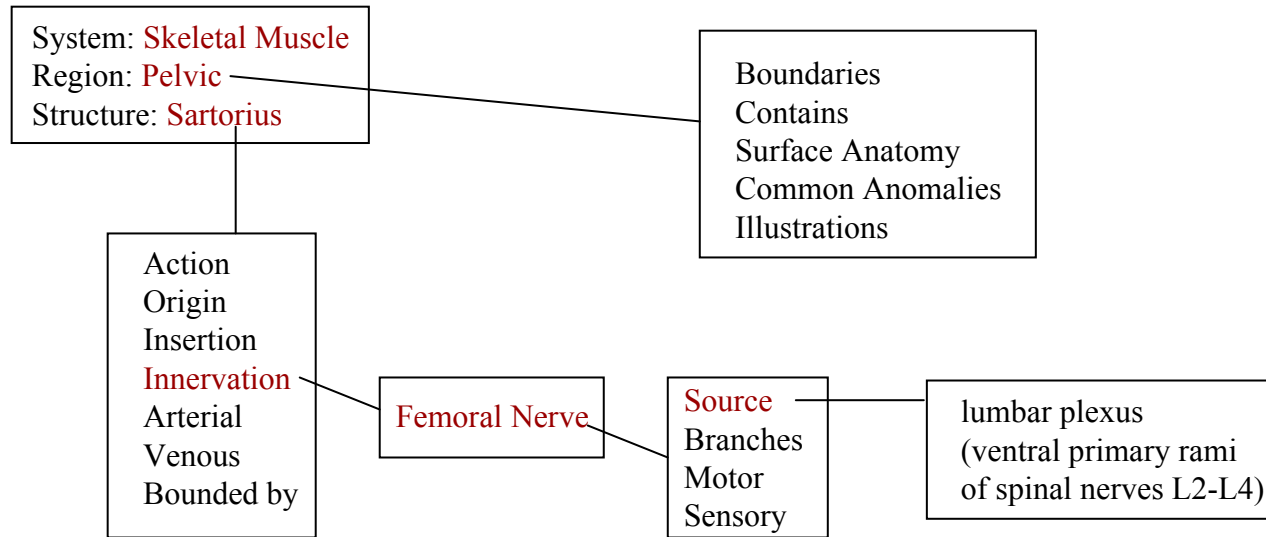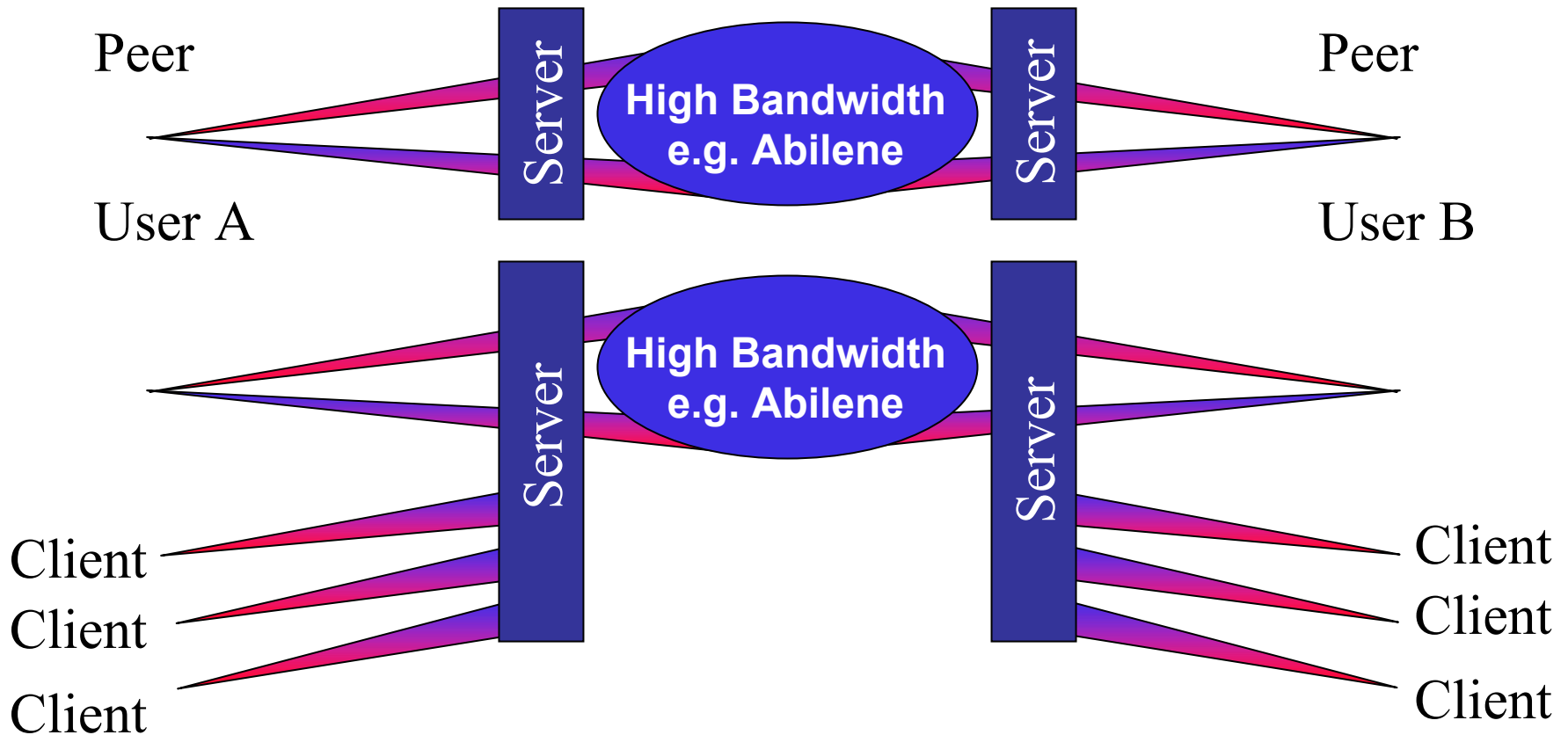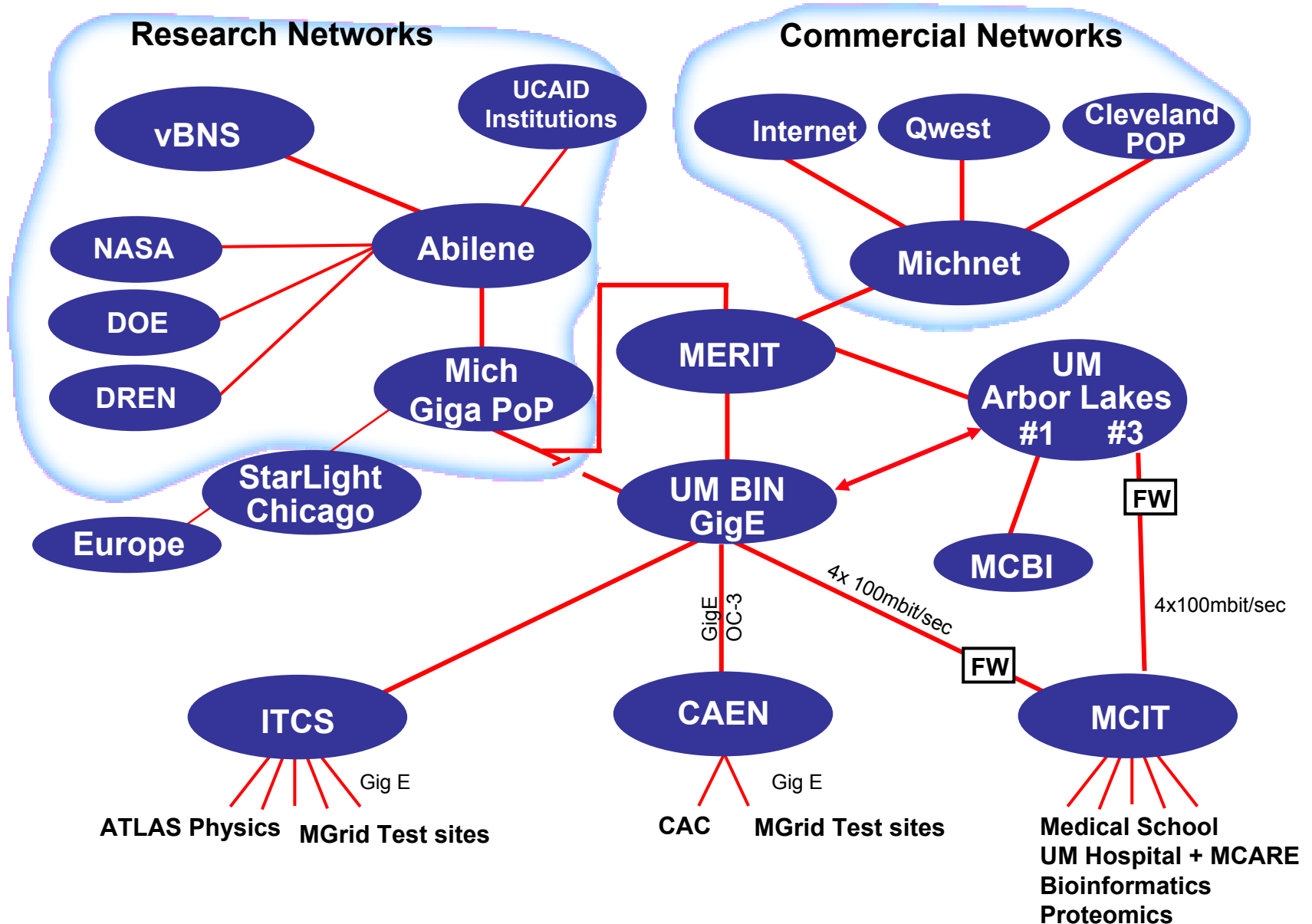
UM VH Database Development

- Over 7000 Terminologia Anatomica (TA) terms are now available via the UMVH database.

- Structural relationships (i.e. heirarchy) imported from UMLS/TA and FMA and linked to VHF content (most now rendered). VHM from Gold Standard is also available.

- Non-English Languages (e.g Chinese).

- Web-based querying and editing.

Clients and Servers and Edges

Peer

Server

High Bandwidth e.g. Abilene

Server

Peer

User A

User B

Server

High Bandwidth e.g. Abilene

Server

Client

Client

Client

Client

Client

Client

University of Michigan Internet Connectivity

Research Networks

Commercial Networks

vBNS

UCAID Institutions

Internet

Qwest

Cleveland POP

NASA

Abilene

DOE

DREN

Mich Giga PoP

Michnet

MERIT

UM Arbor Lakes #1 #3

FW

StarLight Chicago

UM BIN GigE

MCBI

Europe

4x 100mbit/sec

4x100mbit/sec

GigE
OC-3

ITCS

CAEN

FW

MCIT

Gig E

ATLAS Physics   **MGrid Test sites**

Gig E

CAC   **MGrid Test sites**

Medical School
UM Hospital + MCARE
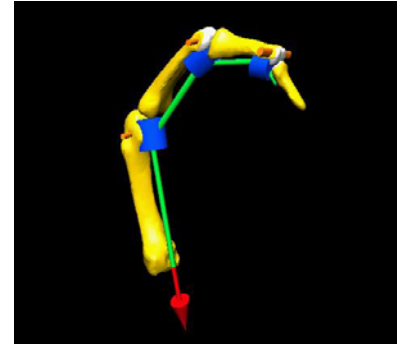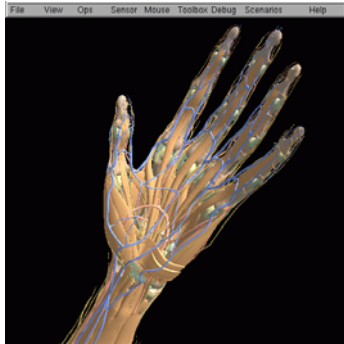**Bioinformatics**
Proteomics

National Test-bed Demonstration at NREN (June 2001): Four Parallel VH Streams— Memory-to-Memory Transfer (UMich to Ames)
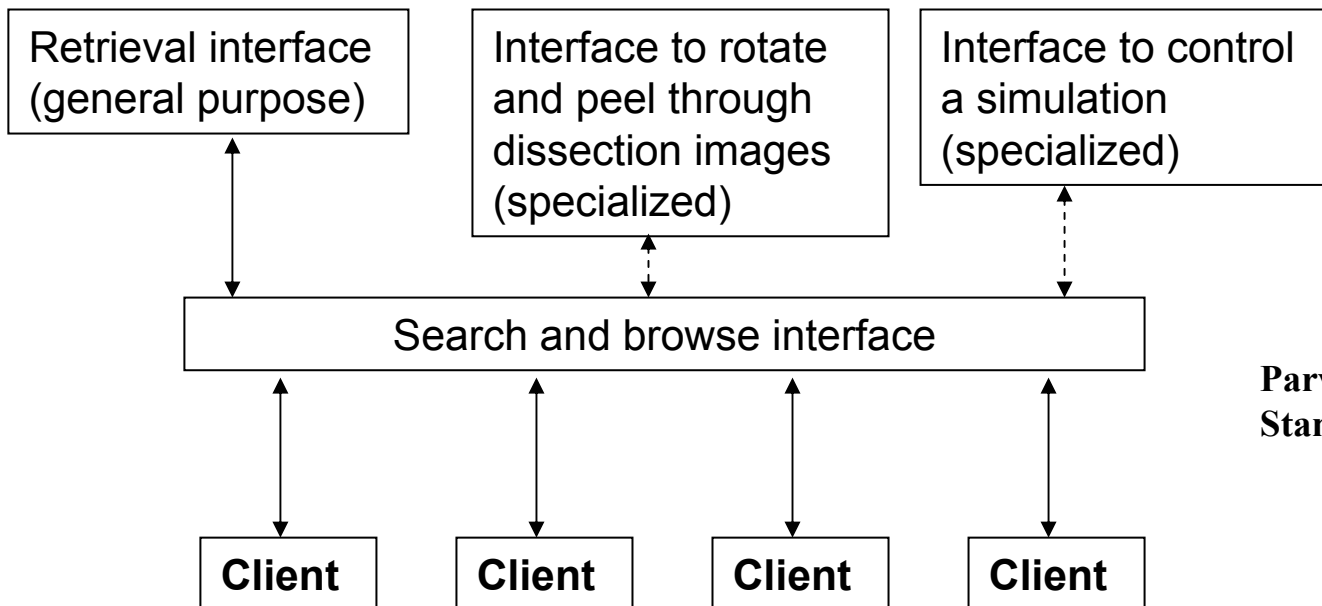
Current UMich I2 Test-bed Network
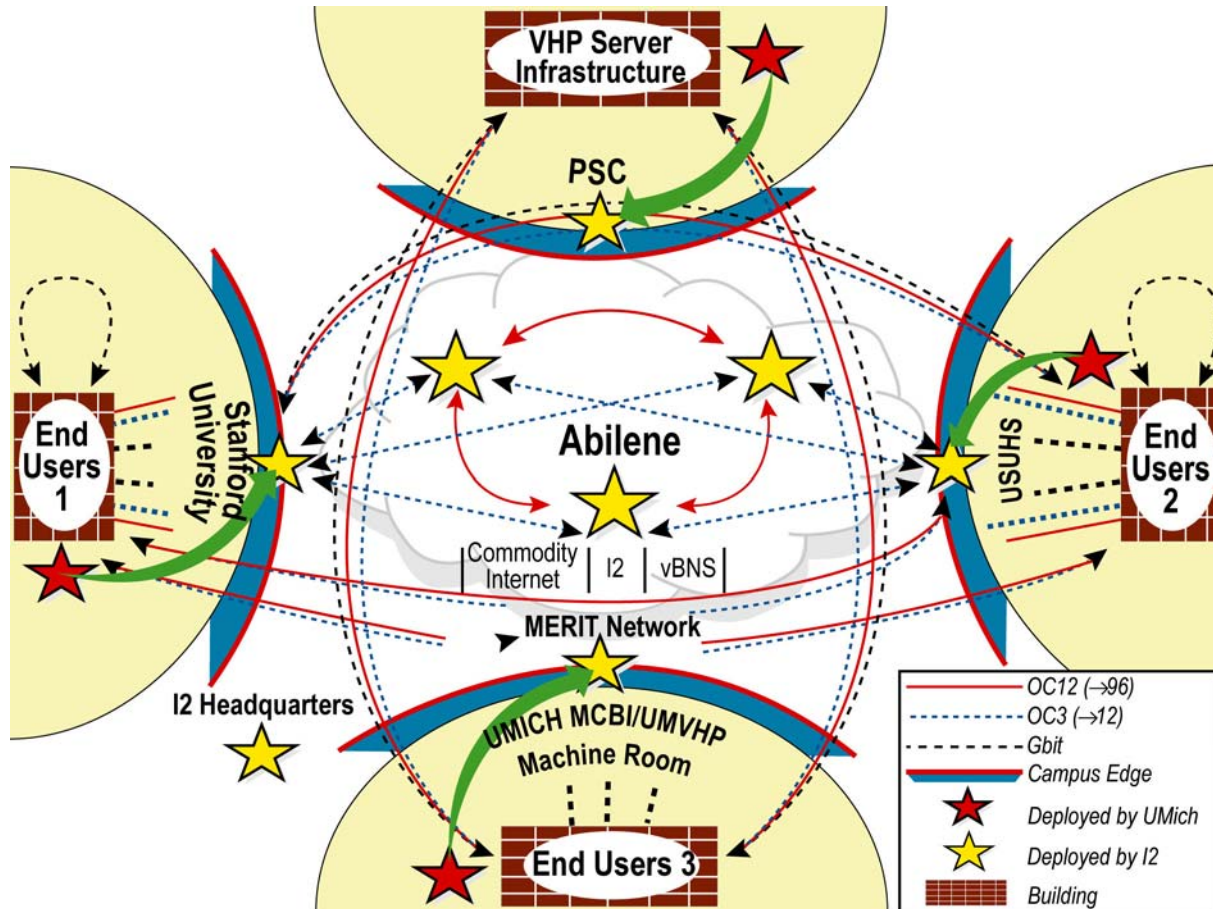
UM is actively Using and Testing the Stanford University Mediaserver
Access to Resources

Library of images and models – A mediaserver

| Retrieval interface (general purpose) | Interface to rotate and peel through dissection images (specialized) | Interface to control a simulation (specialized) |

Search and browse interface

Parvati Dev
Stanford University

Client   **Client**   **Client**   **Client**

Summary: Priorities for Successful I2 Implementation

- High performance campus research backbones must be established
  - Install server capability at the Network Edges
  - Work back to building LANs using optimized paths
- Campus IT officers must be committed to infrastructural upgrades necessary to perform I2 work
- Applications teams must form formal (e.g. contractural) partnerships with campus IT officials

PSC/UMich Server VH Image Data Representation

- Hierarchical multi-resolution tree

- Each node is an 8*8*8 cube

- 4 levels of representation

- Volumetric compression

Voxel Server Specifics: Implementation Approach

- Avoid disk seek and network bottlenecks

- Use memory based server representations

- Apply volumetric compression techniques

- Serve volume data by client demand

- Take advantage of intelligent clients

- Minimize server computational demands

- Leverage network tuning from Web100

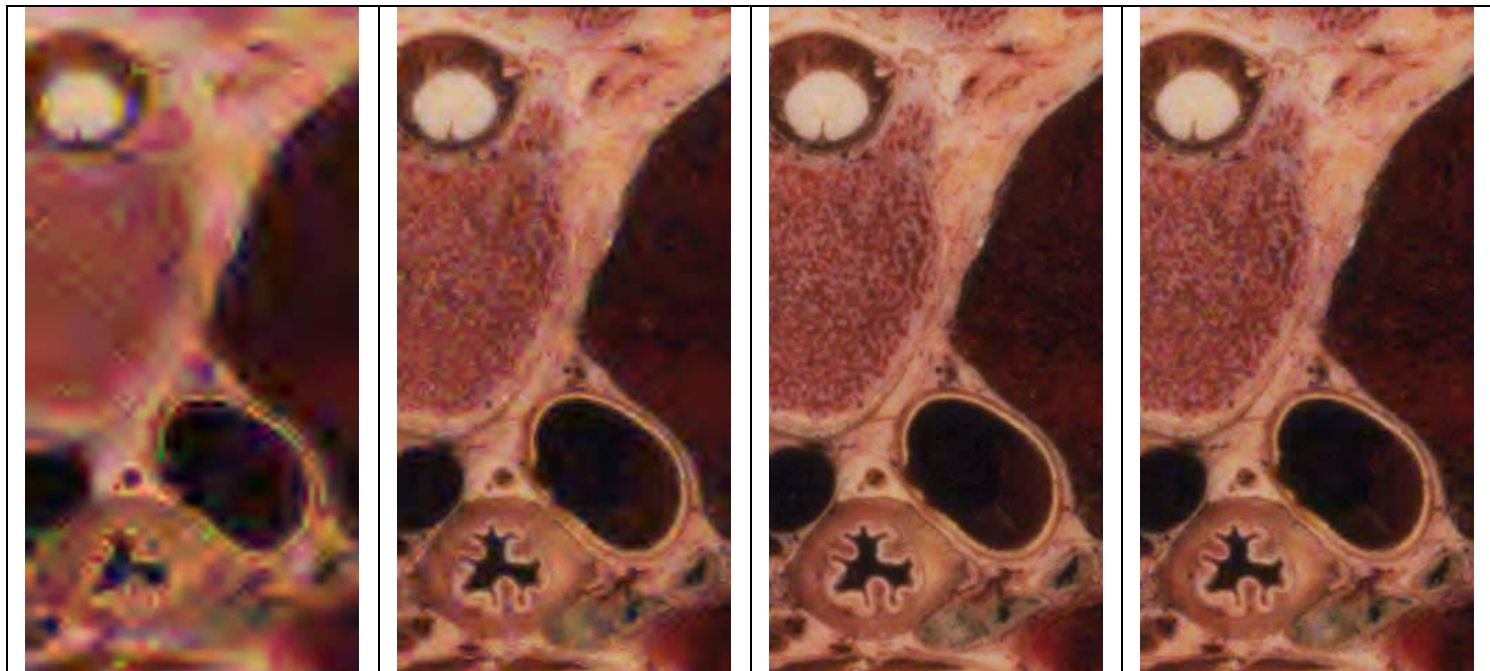# Visual Display of 3 Decades of Compression form PSC tested in UMich Classroom (Wetzel et al.)
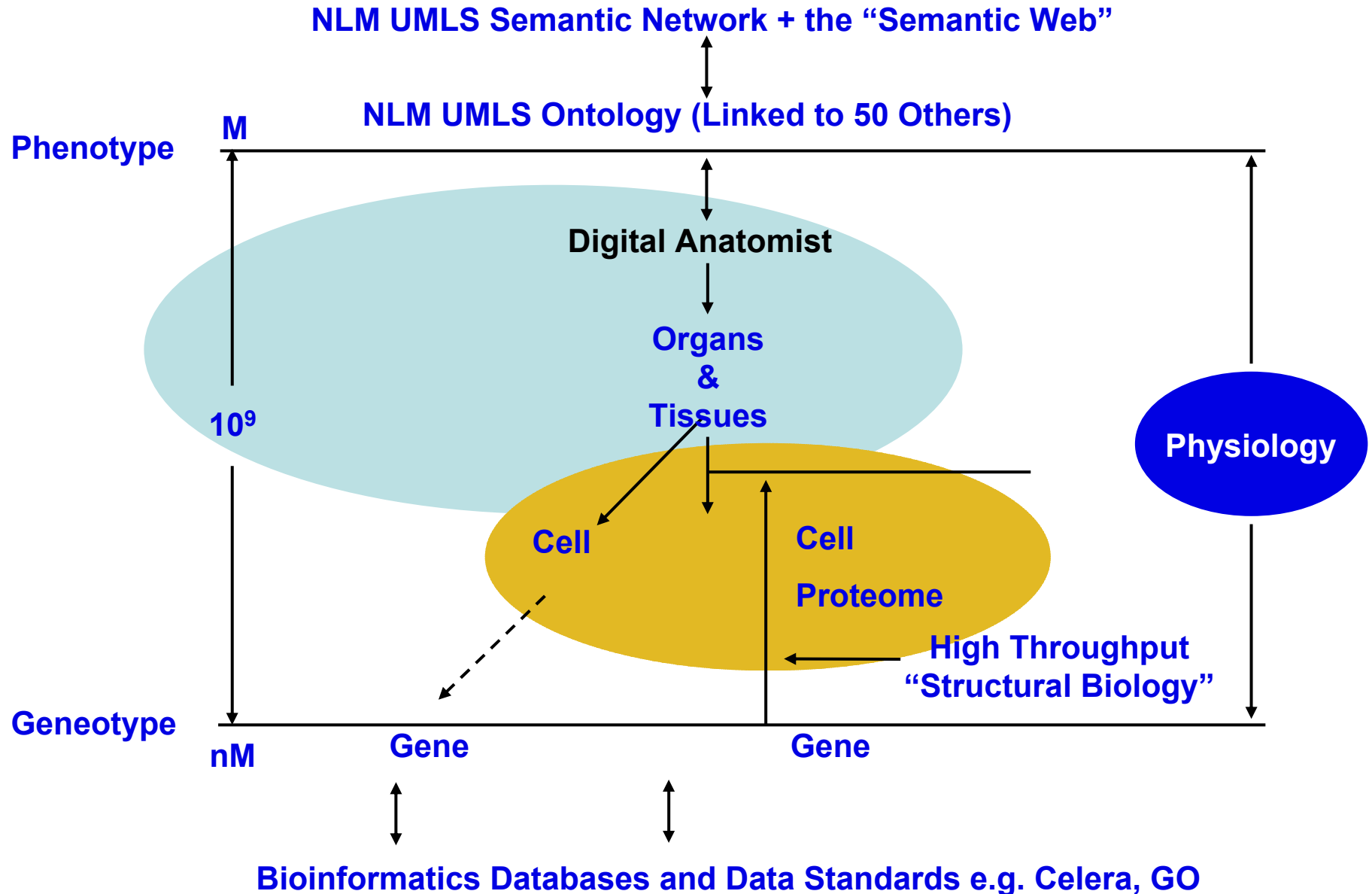

Figure 1. Progressive levels of image quality as image data is delivered at compression ratios of 1150:1, 205:1, 85:1, and 32:1 which is virtually lossless for this portion of the Visible Male 70mm film scan. (From ÒA Networked Environment for Interactively Viewing and Manipulation Visible Human DatasetsÓ by Wetzel.)
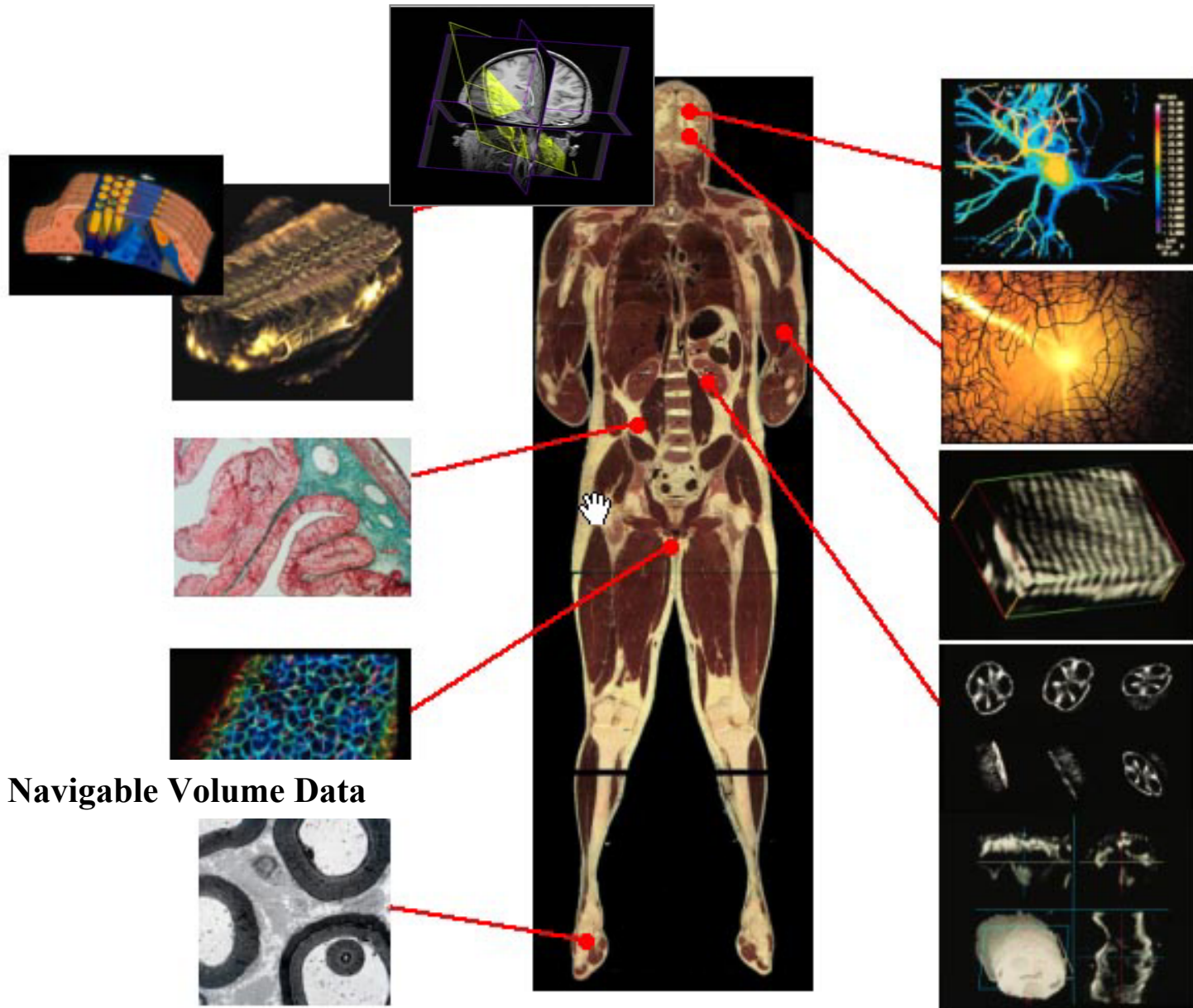
PSC VH Compression Numbers

- Lossy simple VQ   9.42:1 = 2.67Gbyte
- Lossless TS wavelet VQ 7.03:1 = 3.53Gbytes
- Normal JPEG @23.3:1 = 1.06Gbytes
- JPEG2000 estimated ~40:1 = ~500Mbytes
- Lossless SPHIT + arith ~4.22:1
- Lossless SPHIT + huffman ~4.10:1 (2x faster)
- Lossy SPHIT & other EWZ useful beyond 50:1
- Bottom Line: With pre-fetching 50:1 is quite feasible and enables NGI on Cable Modems at full fidelity. I.e. infrastructure is scalable to 1000's of simultaneous users.

# The Future: Ontology Integration and Biological Context

NLM UMLS Semantic Network + the "Semantic Web"

NLM UMLS Ontology (Linked to 50 Others)

M

Phenotype

Digital Anatomist

Organs & Tissues

Physiology

10^9

Cell

Cell Proteome

High Throughput "Structural Biology"

Geneotype

nM

Gene

Gene

Bioinformatics Databases and Data Standards e.g. Celera, GO

Next Obvious Step: Visible Human Extended to 21st Century Histology

Navigable Volume Data

The Current Path to Insertion of VH Data into the Curriculum in a Standards-Based Approach
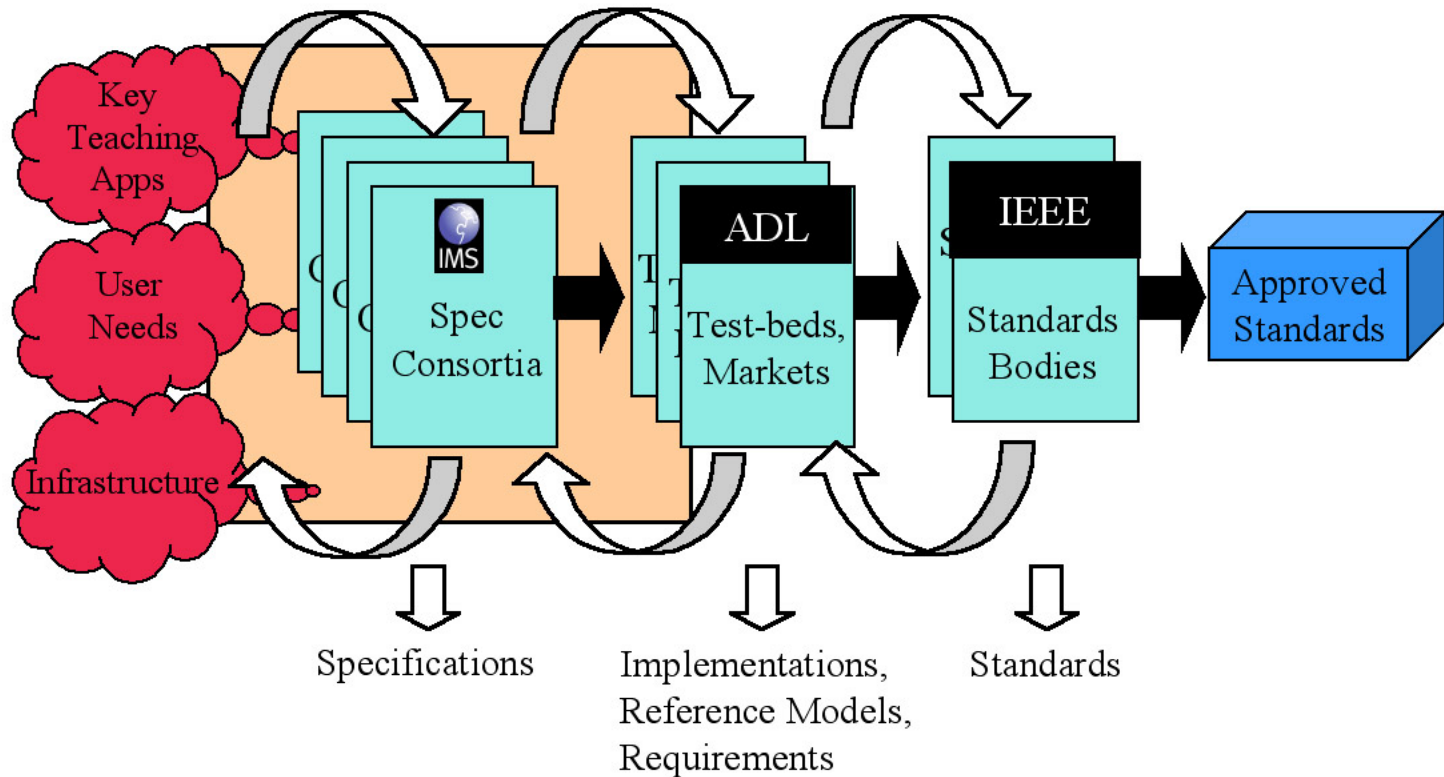
After Phil Dodds. IDA

The UMichTest-bed Includes an Open Source Mechanism Featuring a Standards-based Adaptive Middleware Environment
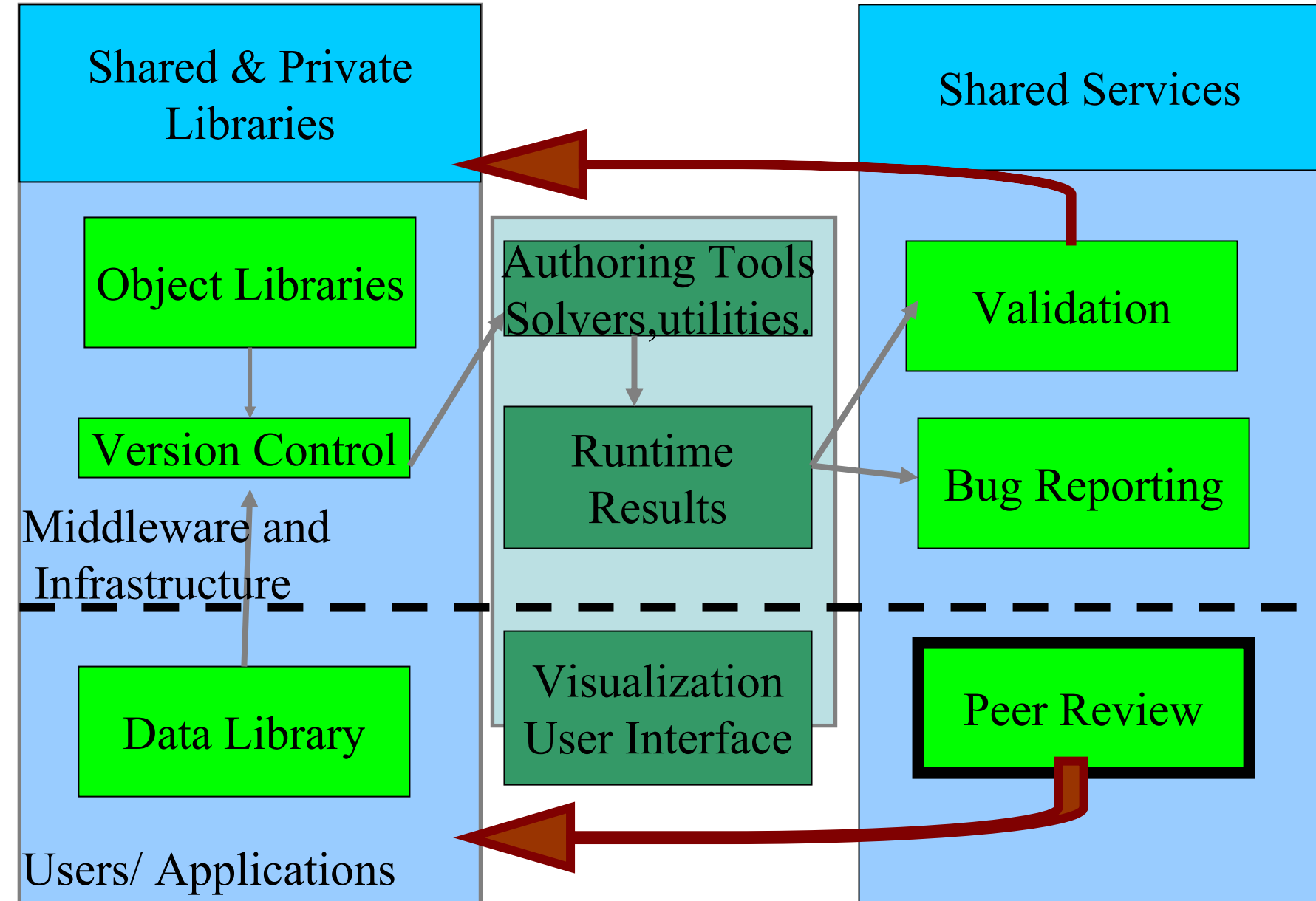
ETF-based Raycasting: Demonstrated by ANL at iGrid 2002 at 800Mbit/s!!!